Richard Ivey School of Business
The University of Western Ontario

IVEY

905N15

INTRODUCTION TO REAL OPTIONS

Jaclyn Grimshaw wrote this note under the supervision of Professors Walid Busaba and Zeigham Khokher solely to provide material for class discussion. The authors do not intend to illustrate either effective or ineffective handling of a managerial situation. The authors may have disguised certain names and other identifying information to protect confidentiality.

In the discounted cash flow (DCF) approach to capital budgeting, the decision rule states that a project with a positive net present value (NPV) should be pursued, whereas a project with a negative NPV should be rejected. This rule implicitly assumes that the project is passively held, and that the only decision that matters is the initial choice of whether or not to invest. In reality, corporate investments are seldom held static for the duration of the investment without further modifications. Most corporate investments are actively managed, with management continuously making decisions and implementing changes to optimize the investment within its dynamic operating environment.

When evaluating corporate investment opportunities, management must thus account for any embedded *real options*. A real option, like a financial option, is the right, but not the obligation, to take further strategic action at a future date with respect to an underlying asset or investment. As such, real options can be valued similarly to financial options and have value ascribed to them based on the time to expiry and the variability and value of the potential outcomes. Unlike financial options, however, real options likely do not have a secondary market that would allow for marking to market the true value of the option and the possibility of a liquidity event.

Overlooking the real options, or option-like characteristics, of a project could result in poor decision-making and missed opportunities. As this note illustrates, projects that have real option features — that is, projects that can be actively managed and modified — can have greater value than those that must be, or simply are, passively held.

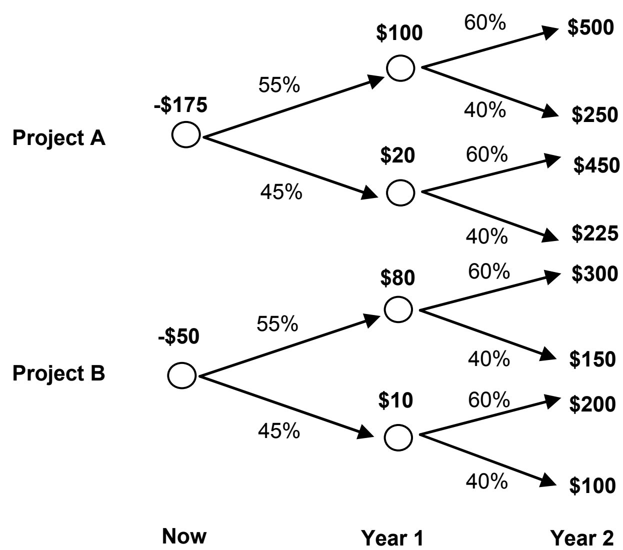
The four main categories of real options are as follows: (i) *expansion and follow-on* options; (ii) *timing and delay* options; (iii) *abandonment* option; and (iv) the option to introduce *flexibility* into production. This note examines the expansion option in detail and briefly discusses the remaining three categories.

DECISION TREES

Decision trees are a useful tool to help evaluate the options inherent in a project. Decision trees also allow for a better understanding of a project's associated risks and rewards by simplifying the investment process into a series of decision points and possible events together with their respective outcomes.

Figure 1 shows a capital budgeting decision where management is faced with the task of selecting between two similar projects. Project A requires a much larger initial investment than Project B ($175 million versus $50 million); however, Project A is also expected to have greater cash flows over its lifetime.

Figure 1 — Decision Tree for Two Possible Projects

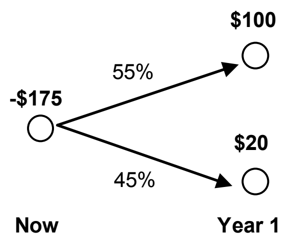


Each circle represents an *event node*, which defines a cash flow (in $ millions) for that period as well as sets the ground for futures outcomes. The payoff tree of each project occurs over two periods, starting at time zero (today) and ending in year two. Probabilities are assigned to each event outcome to specify the likelihood of each outcome occurring.

As a simple exercise, consider the first period of Project A separately (see Figure 2). At time zero, an investment of $175 million is made, and in one year's time, the investment has a 55per cent probability of "high demand" cash flows (i.e. $100 million) and a 45 per cent chance of "low demand" cash flows (i.e. $20 million). To determine the payoff of the first period of Project A, the expected cash flow for year one must be calculated. This calculation is the present value of the weighted average of the probabilities and the event values. The first step is to determine the weighted average of the year 1 cash flows:

$$\mathbf{CF_1} = (55\% \times \$100) + (45\% \times \$20) = \$64.0$$

Figure 2 — Decision Tree for One Period of Project A



The second step is to discount CF_1 back to the present. Assuming the hurdle rate, and thus the discount rate, for comparable-risk projects is 10 per cent, the discounted value is:[1]

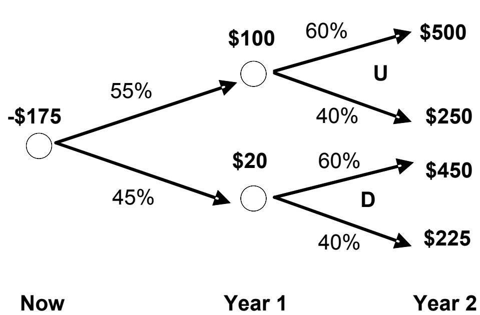
$$PV(CF_1)^{t=0} = \frac{\$64.0}{(1+10\%)^1} = \$58.2$$

This value must then be compared to the initial investment to determine the expected net present value. If Project A were to be one-period only, its NPV would be:

$$\begin{aligned} NPV &= PV(CF_1)^{t=0} - PV(\text{Investment})^{t=0} \\ &= \$58.2 - \$175 \\ &= -116.8 \end{aligned}$$

The procedure of calculating the expected cash flows at a future point in time and discounting back to the previous period is referred to as *rolling back* the decision tree. The procedure can be used to determine the NPV of the entire, two-year Project (Figure 3).

Figure 3 — Decision Tree for Two Periods of Project A



[1] Note that in practice, the resulting cash flow of a project would likely occur over the course of the period and not as a lump sum at the end of the evaluation period. Using the half-year convention (i.e. in this case discounting the weighted average value using a factor of 0.5 rather than 1.0) to calculate the present value may be a more accurate representation. For the purpose of simplicity in this exercise, we assume that the resulting cash flow occurs at the end of the period.

Starting at the far right side of the decision tree in Figure 3, the expected year-two cash flows must be calculated and rolled back to year one as follows:

$$CF_2(U\ region) = (60\% \times \$500) + (40\% \times \$250) = \$400$$
$$PV(CF_2, U)^{t=1} = \frac{\$400}{(1+10\%)^1} = \$364$$

and

$$CF_2(D\ region) = (60\% \times \$450) + (40\% \times \$225) = \$360$$
$$PV(CF_2, D)^{t=1} = \frac{\$360}{(1+10\%)^1} = \$327$$

The process is repeated at the year-one nodes. One of two demand outcomes will be realized in one year. In the "high demand" outcome, which happens with probability 55 per cent, the company receives a cash flow of \$100 at the time (and either \$500 or \$250 a year later). In the low demand outcome (D), the cash flow in one year will be \$20 (and either \$450 or \$225 in two years). The total expected cash flow from the project in one year and the present value of this cash flow now are, respectively:

$$CF_1 = (55\% \times (\$100 + \$364)) + (45\% \times (\$20 + \$327)) = \$411$$
$$PV(CF_1)^{t=0} = \frac{\$411}{(1+10\%)^1} = \$374$$

Comparing the present value of the project's expected cash flows with the investment at time zero gives the project's NPV.

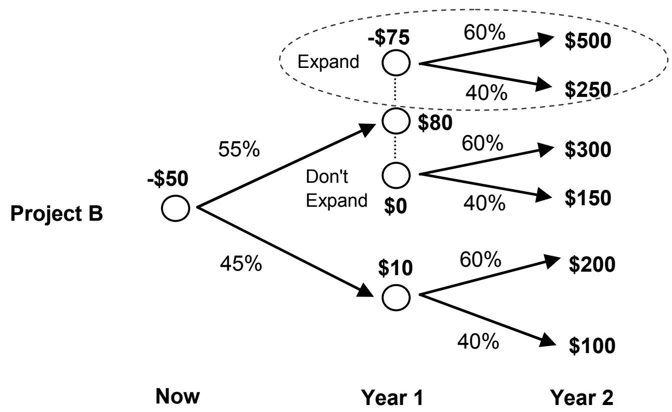
$$\text{NPV(Project A)} = \$374 - \$175 = \$199$$

A similar series of calculations performed on the lower branch of Figure 1 arrive at an expected payoff for Project B of \$163 million. From the decision tree analysis, although the initial cost of Project A is more than three times that of Project B, the expected net present value of Project A is also greater. Thus, if adequate funding is available, Project A should be considered over Project B.

The above example illustrates how decision trees can be used to help facilitate the selection process when deciding between two or more projects. In this example, however, after the initial investment decision was made, no opportunities were available for modifications or further decisions. In other words, the example lacked any real options. What would happen to the investment decision process if management were able to actively manage one of the projects, say Project B, by exercising an option to expand production if demand warranted?

Suppose that if Project B experiences high product demand during year one, management has the option to expand production levels for an incremental capital investment of \$75 million. Figure 4 shows a modified version of Project B's decision tree incorporating the expansion option.

Figure 4 — Decision Tree with Real Option to Expand Project B



To begin the analysis of the modified decision tree, the expansion decision point must be considered first. This decision is evaluated by comparing the payoff of the two choices.

Expand:

$$CF(Expand) = (60\% \times \$500) + (40\% \times \$250) = \$400$$
$$PV(CF) = \frac{\$400}{(1+10\%)^1} = \$364$$
$$NPV(Expand) = \$364 - \$75 = \$289$$

Don't Expand:

$$CF(Don't\ Expand) = (60\% \times \$300) + (40\% \times \$150) = \$240$$
$$PV(CF) = \frac{\$240}{(1+10\%)^1} = \$218$$
$$NPV(Don't\ Expand) = \$218 - \$0 = \$218$$

According to the analysis above, if a high demand materializes in the first year of Project B, further investment to expand production would be profitable. After the action at the future decision point has been determined, the decision branch not chosen is discarded, and only the expected value of the chosen scenario is included when rolling back the decision tree. Hence, if high demand materializes in the first year, the company receives a cash flow of $80 million and expands the project. If, on the other hand, low demand materializes, the cash flow will be $10 million in year one and either $200 million or $100 million in year two. Accounting for the option to expand increases the NPV of Project B to $199 million, just equal to that of Project A. Thus, management must decide which project to undertake based on other criteria.

EXPANSION AND FOLLOW-ON OPTIONS

The decision tree in Figure 4 illustrated that including the option to expand could add incremental value to a project that already had a positive return. Is there ever a scenario in which management would be advised to undertake a project with a negative NPV? At first glance, projects with negative NPV will likely be considered poor investments; however, an option to enter into a new or follow-on project as a result of the initial negative NPV investment can have tremendous value. By failing to consider an individual project within the context of the overall corporate strategy and future flexibility it may provide, management risks overlooking projects that may result in long-term growth and profitability.

Consider PharmCo, a pharmaceutical company faced with large research and development costs to develop a new drug. Upfront research and development (R&D) costs combined with other fixed project costs are estimated at $17 million. Given its seven year drug patent, PharmCo has a limited monopolistic sales life, and the company has projected the present value of net income of the drug to be $16 million. If PharmaCo has correctly estimated its sales projections and expenses, the development of this drug is clearly not a profitable venture on a stand-alone basis.

PharmCo also has the option to develop a second drug in 10 years that would require material use of the research and clinical findings of the first drug. Developing the second drug at that time would require an additional (upfront) R&D investment of $25 million. Based on current market conditions and projected growth rates in the industry, the new drug is expected to generate a value of $38 million (i.e. the discounted value as of year 10 of future expected cash flows is $38 million).

Does this follow-on project look attractive to PharmaCo at the present time? Would the company commit now to future development of the second drug? Committing means investing with certainty $25 million in 10 years in order to create an uncertain stream of cash flows with a present value then of $38 million. Assuming the 10-year risk-free interest rate is 8 per cent and the hurdle rate on projects with comparable risk of cash flows is 15per cent, the NPV of the follow-on project is

$$
\begin{aligned}
&\frac{\$38}{(1+15\%)^{10}}-\frac{\$25}{(1+8\%)^{10}} \\
&=\$9.4-\$11.6 \\
&=-\$2.2
\end{aligned}
$$

The option to develop the second drug is currently out of the money; the project has a negative NPV. But development of the first drug does not commit PharmaCo to the development of the second. The second drug will be developed *only if* conditions in 10 years are such that demand for the drug is strong. Hence, the follow-on option has to be valued as a *real option* not as a commitment.

Although the option can be valued by employing the decision tree methodology introduced above, in the case of follow-on and expansion options, an alternative method can also be used. The characteristics of the follow-on opportunity resemble those of a call option on a financial asset: an underlying asset with uncertain future value (the cash flows generated by the project), an exercise price to purchase the asset (the future investment in R&D), and a future exercise date (when the follow-on project is to commence). Thus, the opportunity to produce and sell the second drug is a call option on the uncertain future cash flows, and

can be valued using the standard Black-Scholes pricing model.[2] Two more parameters are required for the pricing model: a measure of the variability in project value and the risk-free interest rate that corresponds to the term from now until the date of the decision to undertake the project. Table 1 summarizes the inputs for the valuation of the follow-on call option.

Table 1 - Real Option Inputs for Black-Scholes Options Pricing Model ($ in millions)

Input	Financial Options	Real Options Equivalent	Sample Values
S_o	Current price of underlying asset	Present value of expansion project if project were committed to now[3]	$\$38 / (1 + 15\%)^{10} = \$9.4$
K	Exercise Price	Future capital Investment[4]	$25.0
σ	Annual standard deviation of returns	Annual standard deviation of project returns[5]	40%
T	Time to expiration date (in years)	Time until future decision to undertake the project (in years)	10
R	T-year risk-free interest rate	T-year risk-free interest rate	8%

Using these inputs, the Black-Scholes value of the option to undertake the follow-on project is $4.0 million. If the development of the first drug provides the pharmaceutical company with the *option* to enter into production of the second drug, will undertaking the first project now appear more valuable? When the value of the follow-on option is added to the NPV of the first project, the value of the project increases to positive $3.0 million. Because the right to exercise the follow-on option is 10 years hence, creating and preserving the option to expand for an upfront cost of $1.0 million holds significant value. In such phased investments, establishing the right to wait and invest later can often be quite valuable to the overall return of the investment.

TIMING AND DELAY OPTIONS

In the previous section, a project with negative NPV on a stand-alone basis was shown to be a good investment given the embedded real option of project expansion or follow-on. Value can also be realized in the option to delay a project. When the outlook or operating environment is highly uncertain, delaying the project can allow the investor to see how the market will materialize. Delaying a project and timing its market entry could yield much higher returns than if the project is undertaken immediately. On the other hand, if a project appears to be "deteriorating," waiting could result in a lost opportunity and lost cash flows. Thus, management must thoroughly understand and analyze the project to ensure that they optimally time their entry.

Similar to the expansion option, timing and delay options are the equivalent of owning a call option. The option can thus be valued using either the Black-Scholes formula or the binomial model; the latter provides management with the ability to determine the optimal timing.

---

[2] For a description of the Black-Scholes option pricing model, see same authors, "An Introduction to the Pricing of Options," product # 9B05N014, Ivey Management Services, 2008.
[3] For this example, an investment hurdle rate of 15 per cent was assumed.
[4] The exercise price or future investment is assumed to be a known, fixed number.
[5] Variability is determined by evaluating comparable traded stocks with similar business risks and investment opportunities.

ABANDONMENT OPTIONS

When management evaluates capital budgeting decisions, it assumes an investment lifespan and forecasts the expected cash flows to that date. However, not all investments turn out as projected; forecasted product demand could fail to materialize or the expenses associated with the project could escalate beyond projections. In either situation, the option to abandon a project and salvage any remaining asset value can help save the company from further losses.

Similar to a put option, exercising an abandonment option is advantageous when the value that could be obtained by selling off the assets is greater than the value of continuing with the project. An abandonment option gives the company the opportunity to mitigate losses on a failing investment.

The binomial method can be applied to projects to both value the abandonment option and to solve for optimal abandonment. As with all projects, the first step is to value the underlying project or assets on a stand-alone basis.

FLEXIBILITY IN PRODUCTION

Flexibility in production refers to the option to vary the level of production, the product mix or the production method itself. Varying the level of production or product mix to match consumer demand helps to ensure that a company can sell its products for maximum return. Flexibility in production methods can allow for switching between raw materials based on which materials are currently available at the most competitive price.

SUMMARY

Most capital investments or projects contain real option characteristics resulting from management ability to dynamically make adjustments (expansion, follow-on investments, abandonment, or continuing to wait) as market conditions evolve. Valuing these projects requires proper identification and valuation of the embedded real options. As this note has demonstrated with simplified examples, decision trees are a useful tool to analyze and value projects with real options. In practice, corporate projects and investment decisions are much more complex, containing significantly more decision points. The simple methodology introduced in this note can be extended to deal with the added complexity of the real-life situations.